SILICON TO IRON ABUNDANCES IN SOLAR COSMIC RAYS AND IN THE SUN

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ABSTRACT

Differential spectra of even charged nuclei between Si and Fe in the August 4, 1972 event are made in the energy region of 10 to 40 MeV/n-1 using rocket borne plastic detectors. The resultant relative abundances of elements and low energy (E < 25 MeV n-1) enhancements are obtained. Comparison with spectroscopically determined photospheric abundances is also made. The implications of these relative abundances on the acceleration mechanisms is discussed.

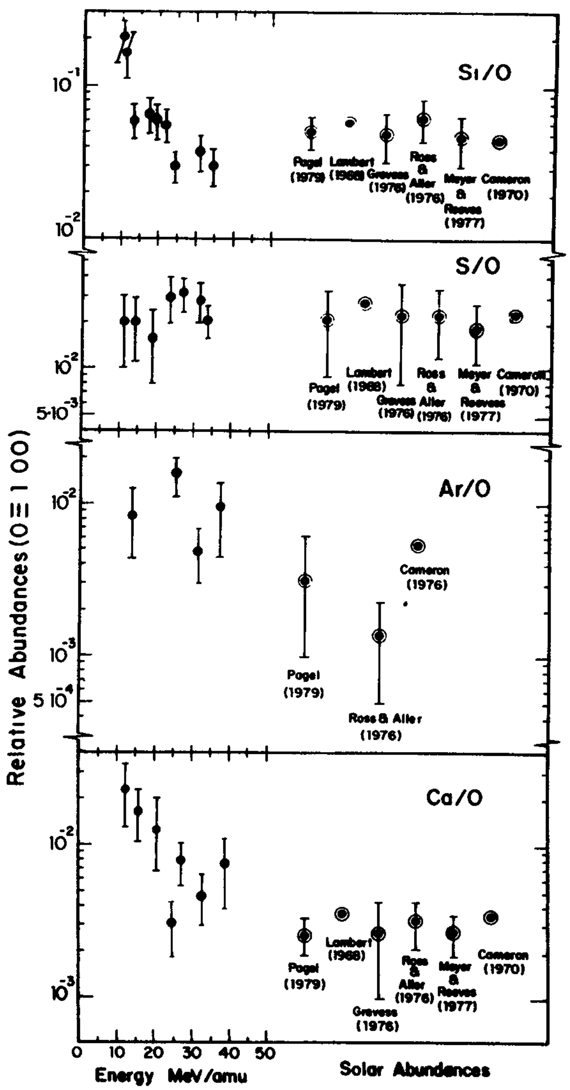
1. Introduction. With rocket flights and solid state nuclear track detectors, large flares have been studied in great details and it has been shown that at the higher energies (E > 25 MeV/amu) the relative abundances tend to match the photospheric abundances (Bertsch et al 1974; Biswas et al., 1983; Crawford et al.,1975). August 4, 1972 was amongst the largest events with large heavy ion fluxes. Data of good statistics on relative abundances for even charged nuclei between Z = 14 to 26, were obtained in this flare. The results are discussed in this paper.

2. Experimental Method. The study of the August 4, 1972 event was done with a stack of 23 sheets of Lexan polycarbonate flown on a sounding rocket in NASA's SPICE programme from Ft. Churchill, Canada at 1916 UT to study the emission from an optical flare of 0617 UT the same day. The rocket was spin stabilised and reached an altitude of 160 kms above earth. The rocket nose cone was opened at an altitude of 60kms on ascent and closed at 85 kms on descent giving a total of 245 seconds of exposure (see Durgaprasad et al.,1982).

The plastics were recovered and processed in 6.25 N NaOH solution at ($40 \pm 0.1°C$) for 4 hours to reveal the tracks of Z > 12 elements. A total area of 30 sq. cms. was studied at different depths to determine

the spectra. The details of the technique are discussed elsewhere (Vahia, 1983).

Fractional charges were assigned to the tracks using the constant energy contours. The Gaussian of all charge values for all the events had FWHM for Si as 0.24 and for Fe as 0.33 charge units. From this the differential spectra were determined. The differential spectrum of Fe obtained by us was compared with that obtained by other investigators on the same flight and good agreement was found. The oxygen spectra were taken from the measurements by Bertsch et al (1974) made in the same flight. The relative abundances are plotted in Fig. 1



3. Results. In the case of odd charges, only 13 Al, 15 P, 17 Cl, 23 V and 25 Mn have observable flux values. It should however be noted that since the processing of the sheets was done to study Z > 14 elements, the aluminium events are subject to detection efficiency and its relative abundances need not be considered for the present study.

Fig. 1a Variation of relative abundances as compared to oxygen of Si, S, Ar and Ca nuclei with energy and comparison with photospheric value.

As for other observed elements, with the notable exception of Mn, they are seen in very small numbers and no definite flux measurements can be attempted. The Mn fluxes can be determined only approximately by the method of histogram subtraction. In the entire energy range Mn/O ratio is about 0.10. This is a factor of about 10 above the spectroscopic determination of 0.008 ± 0.005. In our study we observed a high Mn/Fe ratio of 0.15 (~20 events) in sheets 2 and 3 (energy 10-25 MeV/amu). In the sheets 4-5 and 8-9 we saw no appreciable flux of Mn implying Mn/Fe < 0.01. Hence it seems that Mn must be having a steeply falling spectrum. This would result in a steeply falling enhancement between 10 and 40 MeV/amu. Therefore the Mn observations seem to be consistent with the photospheric determinations within experimental approximations. The elements Si, S, Ar, Ca, Ti, Cr and Fe are seen in sufficiently large numbers to help in determining detailed spectra of these elements. Their charge histograms are also distinct and devoid of possible contaminations. Hence flux determination can be made accurately and with a high degree of confidence.

At low energy, the more abundant elements for which detailed study is possible show varying degrees of enhancements.(Figure 1)

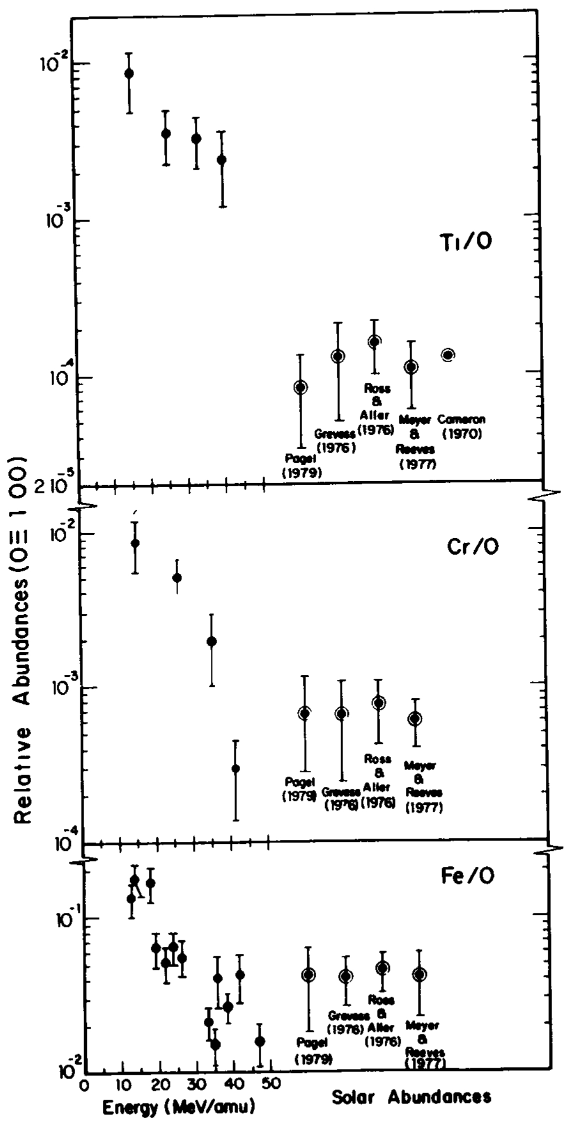


Fig.1b Variation of relative abundances as compared to oxygen of Ti, Cr and Fe nuclei with energy and comparison with photospheric value.

This is given in Table 1 for E between 10 and 20 MeV/amu.

Table 1 : Enhancement factors of Si-Fe elements in August 4, 1972 event

Element	Solar abundance Pagel (1979)	Energy Interval	Abundance relative to oxygen	Enhancement factor
Si	(0.052±0.013)	10-16	(0.12±0.05)	2.31±1.12
		16-20	(0.058±0.024)	1.12±0.54
S	(0.021±0.012)	10-20	(0.020±0.009)	0.95±0.69
Ar	0.0031	10-20	(0.0097±0.0055)	3.06±1.25*
Ca	(0.0026±0.0007)	10-20	(0.020±0.009)	7.69±4.03
Fe	(0.042±0.024)	10-20	(0.131±0.052)	3.12±2.17
		20-25	(0.085±0.035)	2.02±1.42

4. Conclusions. In this study the differential spectra of Si,S,Ar,Ca,Ti,Cr and Fe were determined between 10-40 MeV/amu during Aug.4,1972 event. The Fe differential spectra were checked with those determined by other investigators using the same flight exposure. The agreement was found to be good. The oxygen spectra determined by Bertsch et al (1974) in the same flight were used to determine the relative abundances with respect to oxygen. At low energies (10-20 MeV/amu) the abundances were found to be enhanced over the photospheric value and at high energies(E>25MeV/amu) the values agree with the solar photospheric values in general. In most casesthis study has resulted in more accurate determination of the high energy SEP compositions which may be used interchangably with the solar photospheric abundances as representative of the solar surface matter.

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